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General Engineering Problems of the Bell System

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NOTE: This paper, read before the Bell System Educational Conference, Chicago, June 22-27, 1925, discusses the character and scope of the important problems involved in caring for the growth and operation of the Bell System. The plant extensions necessary to meet service requirements and the necessity of advanced planning are first taken up. The uses of the "Commercial Survey," the "Fundamental Plan" and engineering cost studies are analyzed to illustrate how an engineer attacks the problem of furnishing satisfactory telephone service to the public. A discussion of the New York-Chicago toll cable and the telephone problem in New York City, as illustrative of specific engineering problems, concludes the paper.

THE problem of giving telephone service is quite different from that of most business enterprises. The merchant, for example, may take more business in his store without necessarily always increasing his facilities. The minute we take another subscriber, however, we add to our plant and plant investment. Similarly, in connection with the manufacturing industry, the manufacturer, for instance, is in a position to exercise very direct control over his activities. In the telephone industry, however, our obligation is to take the service as requested and be prepared to deliver it when and as it is required. Furthermore, the activities of the telephone business are of such a nature as to make it essential, regardless of the remoteness of the territory or of the physical and climatic conditions involved, that a way be found, as far as practicable, to construct and maintain the plant and safeguard the service to the public.

To meet these exacting requirements calls for the greatest ingenuity and foresight in the design of the telephone plant and involves careful study of various plans for plant extension and rearrangement with a view to the selection of the most economical and desirable plan. Having determined the fundamentals of design, there must, of course be devised ways and means of safely constructing and efficiently maintaining the plant. Furthermore, as the plant is necessarily scattered over a very large territory and as the different parts must work together satisfactorily and with the most economical results, a high degree of standardization is required, still leaving, however, freedom to adapt the plant to different local conditions. We find evidence on every hand of the value of this standardization, not only

during normal conditions, but also during emergencies, when it has been possible to quickly assemble equipment or materials from any part of the system and promptly restore or expand the service as required.

Important engineering problems of great variety, therefore, present themselves on every hand calling for consideration by the engineers in the General Engineering Departments, as well as the Traffic, Plant and Commercial engineers associated with the operating divisions of the companies.

Plant Extensions to Meet Service Requirements

A very large part of the engineering work of the Bell System is concerned with the design of plant extensions to meet expected future service requirements with the maximum economy consistent with maintaining the service standards of the system. I shall not discuss the magnitude of the various activities and requirements of the system, but will recall to your mind a few of the outstanding items to better illustrate the magnitude of this part of the engineering work.

Telephone stations are being connected at the rate of over two and one-quarter million annually.

The resulting net additions or gain in stations per year is approximately 800,000.

To meet this station gain and to replace equipment removed from plant, switchboards are being added at the rate of approximately 1,200,000 station capacity annually.

The Bell System installs in one year approximately 30 billion feet of insulated conductor in lead covered cable ranging in unit sizes from 1 pair to 1,212 pairs. Of this amount, more than 27 billion conductor feet constitute the net annual increase in conductor mileage.

The above plant additions, together with other important items, such as poles, wire, etc., involve a net increase in the telephone plant of nearly three hundred million dollars annually.

It is of interest to note, in this connection, that the annual additions to the telephone plant today are equivalent to the entire plant in service in the Bell System as of about 20 to 25 years ago.

Necessity for Advance Planning

Obviously with a program of this magnitude and of such diversity in the character of its related units, careful advance planning is necessary to insure economical and satisfactory performance.

In the earliest days of the telephone service, the problem of laying out a telephone plant was a simple one. A very small switchboard, simple in character and easily moved, if necessary, was placed in some convenient location, usually in rented quarters, and from that switchboard wires were run one by one as needed, to the premises of those desiring service, either on poles or over house-tops. Under such simple and rudimentary conditions, no serious question of the future needed to be answered. Today, how different is the telephone situation in many large cities, such as Chicago, or throughout the system. Large and specially designed buildings must be constructed for the accommodation of the necessary interconnecting or switching mechanisms; expensive switchboards must be placed in these buildings; conduits must be extended from each of these buildings along appropriate routes to reach the thousands of telephones which receive service from these switchboards; other conduits must be placed between these switchboards and the other buildings and switchboards throughout the city so as to provide the means of intercommunication between the subscribers connected with the switchboards located in different buildings; still other conduits and cables must be placed between these switchboards and the central switchboard or toll board from which radiate cables and conduits and lines extending to the suburban area, to adjacent cities, to all the other principal cities in the United States, and to Canada.

Each of the buildings must be placed in some definite location and it is necessary to plan this well in advance and to direct the growth of the plant toward that location, even though the building may not be built for some years hence. Otherwise, very serious and costly rearrangements of plant would be necessary at the time the office is opened. Furthermore, each building must be planned for some definite ultimate size, although, of course, the whole building need not be built at one time. Ducts cannot be placed under the streets one by one as needed. Public sentiment would not, of course, tolerate the opening of important street routes several times, or even once, each year for the purpose of placing an additional duct. Neither would it be economical, if practicable, to construct conduits in this piecemeal way. The manholes in these conduits must be planned with reference to the number of ducts extending into them, not only the ducts initially placed, but if side runs are to be made from these manholes or if other ducts are to be placed later, this fact must be foreseen and provided for, or extensive and expensive alterations are inevitable at a later date.

I might go on and multiply the conditions which must be met in constructing telephone plant in a country such as ours in which not

only the population is growing and moving, but where the demand for telephone service is growing more rapidly than the population. We are in effect planning a growing organism and we must recognize that we are dealing with ultimate tendencies largely beyond control, the effects of which are not capable of exact valuation. However, enough has been said, I believe, to indicate clearly to you that the telephone company on every item of its buildings, conduits and cable construction must constantly answer for itself vital questions as to the future requirements of the system.

This was early recognized, and one of the most important engineering problems of the Bell System has been the formulation of estimates of expected future telephone business both as to quantity and expected location, and the development, from these estimates, of basic plans of procedure, which plans must, of course, be flexible, capable of modification from time to time, and such modifications must be made as changing conditions show them to be advisable.

Our first step in determining the estimated future telephone requirements is to prepare a so-called "Commercial Survey" of the city, covering the requirements fifteen or twenty years ahead. These studies include a critical analysis of the existing market for telephone service, pertinent facts as to the present sale of telephone service, of classes of service and users and forecasts of the market for telephone service at the future date or dates. Consideration is also given to the growth and distribution of population, expected changes in general wage levels, etc., and assumptions of the amount of business that must be sold in each area on the future dates selected under assumed rate conditions.

Having thus determined from the "Commercial Survey" the requirements for telephone service for various parts of the city at the future date assumed, it is next essential to develop a comprehensive plan to serve as a basis for the layout of the plant to meet these requirements. Accordingly, a so-called "Fundamental Plan" is made for the community covering these conditions as estimated fifteen or twenty years hence. The importance of such a plan is obvious, but a brief reference to some of its features will, I believe, be of interest.

In laying out a plan for a city, the engineer might, as an extreme case, center all the subscribers' lines at one building. Obviously, we would have a maximum efficiency in operation in some respects, in that we had grouped all of our switchboards together, but our outside plant costs would be at a maximum and other disadvantages would be experienced. As the other extreme, the engineer might place many

small buildings around the city, thus placing the outside plant costs at a minimum, but increasing the difficulty and expense of operating so many centers. Obviously, therefore, there is some arrangement between the two extremes I have cited which would provide the most economical and satisfactory layout of the plant. Several test cases, which in the judgment of the engineer seem promising, are, therefore, studied and the most economical and satisfactory plan determined upon. In completed form, these "Fundamental Plans" furnish us the following essential information upon which to proceed with the more detailed studies covering plant extensions.

a. The number of central office districts which will be required to provide the telephone service most economically and the boundaries of these central office districts.

b. The number of subscribers' lines to be served by each central office district.

c. The proper location for the central office in each district to enable the service to be given most economically with regard to cost of cable plant, land, buildings and other factors.

d. The proper streets and alleys in which to build underground conduit in order to result in a comprehensive, consistent and economical distributing system reaching every city block to be served by underground cable.

e. The most economical number of ducts to provide in each conduit run as it is built.

Our experience has shown that these fundamental plans reduce guesswork to a minimum by utilizing the experience of years in studying questions of telephone growth in order to make careful forecasts on the best possible engineering basis. These fundamental plans, together with related studies, thus provide a general program of plant extension to be followed throughout the period for each of our cities and somewhat similar plans are, of course, undertaken for determining the future requirements of our intercity or toll facilities.

It is evident that both the ultimate arrangement and the program whereby it is to be obtained must have the utmost flexibility in order to meet unforeseen requirements, must work in satisfactorily with the existing plant, which represents an investment of over $2,500,000,000 must meet immediate service requirements, and also permit full advantage being taken of new developments in the telephone art.

The specific or detailed plan for each project of plant extension, whether within the cities as discussed or between cities in the toll line

plant must, of course, be started early enough so that adequate time is allowed for completion of the construction work before the new facilities are required. The complete interval between starting work on such a project and getting it into service can seldom be less than one year and in the case of building and central office equipments must, of course, be longer.

Engineering Cost Studies

Owing to the complexity of the problem of suitable advance planning for the growth in the telephone plant as already discussed, it is evident that in the study of plans for specific projects, selection must generally be made between a choice of arrangements, more than one of which might satisfactorily meet the requirements of the service. It is usually necessary, therefore, that two or more practical plans or programs for construction must be compared so that the most advantageous plan may be selected. An important factor in the selection of all of these cases is a study of the relative economies of the different plans; that is to say, a comparative cost study and as these studies form such an important part of our engineering work, I believe it will be of interest to devote a few moments to a description of the important considerations generally involved.

These engineering cost studies require analysis and consideration of the cost and resulting annual charges for different amounts and types of plant included under each plan. The annual charges comprise items of expense incident to ownership of plant and those that are incurred each year after its installation to keep it in operation and in serviceable condition. As a general thing, in these cost comparisons, another interesting factor is also present; namely, most of the plans which are compared call for expenditures to be made at different periods. For example, one plan might call for erecting a new building at a new location immediately; whereas under the other plan being considered, the necessary additional space required could be secured by adding to an existing building and deferring the complete new project for possibly five or ten years. The relative economy of the plans, therefore, cannot be determined directly by a detailed comparison of the expenditures involved or resulting annual charges, but it is necessary in order to give a fair comparison to express the relative costs of the different plans in terms of present worths, or equivalent annuities which give figures for the total expense in which accurate allowance is made for the variation of expenditures with respect to time.

These engineering cost comparisons may be considered as composed of four parts or operations; namely, the premises or known factors and assumptions; the formulation or set-up of the problem; the solution or mathematical calculations and finally the interpretation of the results. The determination of the premises and formulation of a given problem is, of course, a matter specific to that problem, and here the engineer must exercise sound judgment, for unless the assumptions upon which the work is based are reliable the study itself is of little value. The mathematical calculations are, of course, a definite thing. However, the interpretation of the results must always be a matter of engineering judgment and full weight must be given to those factors which by their nature cannot be evaluated in the cost comparison.

A cost study is a fundamentally important tool in assisting the engineer to reach a decision as to the most desirable plan or program, but as indicated it cannot be used to replace the exercise of judgment on his part. The solution of an engineering problem is, in general, not a matter that can be demonstrated mathematically as can, for example, the proposition, that the square of the hypotenuse of a right triangle is equal to the sum of the square of the two sides. An engineering study rather requires in addition to all of the definite facts that can be brought to bear on the question the exercise of sound judgment on the part of the engineer in weighing the results of the cost study with all related business or other factors bearing on the problem.

Some factors involved in these engineering studies are often of a character which do not permit of expression as a direct charge against a given plan, but must be considered on a broader basis such as the difference in quality or dependability of the service, etc. Also it is important to keep in mind, for example, that, other things being equal, a plan requiring large investments has disadvantages as compared with one requiring a smaller investment so that even though the plan involving a larger investment may prove in from the cost study by a small margin, it may be desirable to adopt the alternative plan so as to avoid tying up considerable amounts of fixed capital. Another question to be kept in mind in interpreting cost studies is whether the more expensive type of plant, usually a higher type of plant, can be adopted satisfactorily at a later date or whether the decision to be made at the present time precludes its adoption later. In the former case it is often wise to go further in deferring fixed capital expenditures than in the latter case. Finally, throughout all of his work the engineer must have foremost in his mind the fact that the telephone system exists for the purpose of furnishing service to the public and the

results of his engineering effort should insure a service which is satisfactory from the subscriber's viewpoint.

It is evident from what has been said, I believe, that these engineering cost studies are of great benefit in working out the proper procedure in our engineering work, and I assume they are equally helpful in the engineering of any kind of growing plant. Anything that can reasonably be done, therefore, to give the student an appreciation of the nature, scope, and application of the economic considerations of these engineering problems and to develop his faculties of judgment, imagination, team play, and other related qualities, will doubtless prove of great value to the student in his later engineering work.

Other Phases of Engineering Work

I have thus far described to you some of the very important engineering problems involved in the planning and carrying out of plant extensions to meet expected future service requirements. I would like next to consider with you a few of the engineering problems that present themselves in the actual design or operation of these large extensions to plant as introduced.

The rapid development of the telephone system, including the tremendous growth in the number of telephones in service and the rapid increase in the extent of territory which can be reached from any telephone, has led to a great increase in the importance and difficulty of the technical problems involved in the design and maintenance of the plant.

These technical problems cover a very wide range. The electrical and acoustic problems involved in the transmission of speech have led telephone men to much pioneering work dealing with the flow of sustained and transient alternating currents in electric circuits of all types and in the fundamental nature of speech and hearing itself. Again, the economical design of outside plant with suitable strength and economy involves investigations of characteristics of construction and materials and the preservation of timber, and there are, of course, special mathematical and other problems involved in the design of long cable or wire spans. Buildings and associated central office equipments involve very interesting mechanical and electrical problems in the matter of the layout of the buildings and the arrangement of apparatus to meet exacting requirements. These include many problems in the design of means for automatically supervising the progress of telephone connections and in the design of thousands

of types of apparatus to meet specific mechanical and electrical requirements.

What I have already said emphasizes the importance of engineering work involved in the design of new plant. Very interesting engineering studies are, however, also involved in connection with the maintenance of the plant as well. This includes the development of improved maintenance methods and routines and a critical analysis of the results obtained, judged from the points of view of excellency of the service and economy of operation. To use a homely illustration: one might have his automobile completely gone over by a garage every 100 or 200 miles of running with the result that he would probably be reasonably sure of perfect maintenance of the automobile (assuming a perfect garage), but the maintenance costs would be excessively high and out of proportion to the benefit received. On the other hand, however, if no attention is given to the maintenance of the automobile, maintenance costs would be at a minimum but the depreciation would be high, the operation would soon become unsatisfactory and sooner or later the results would be a total interruption to service use. The problem, therefore, evidently is to find the proper balance between overall costs and service results, and this is true, of course, of the various engineering problems to be solved in connection with the maintenance of the telephone plant.

The engineering work of the Bell System also involves, to a large extent, relations with other organizations. These relations are very close with other wire-using companies, including small telephone companies whose lines connect with those of the Bell System. Important relations must be maintained by the engineer with electric power and electric railway companies, as particularly important problems of safety and of service arise due to the proximity between their electric circuits and the telephone circuits. These problems involve provision not only for the protection of the plant and employees against the danger of contact with the wires of other companies but also include coordination of the two systems to prevent excessive inductive effects which often become important where electric power lines or electric railways and telephone lines run parallel to each other. The electric companies and the telephone companies often find it advantageous to enter into arrangements for the joint use of pole lines and this presents many problems requiring consideration by the engineer. It is evident, therefore, that the problems of the telephone engineer cover a very wide and interesting field in mechanical, electrical and other arts, both within the business itself and in relation with other utilities and municipal, state or national bodies or associations.

Specific Projects Illustrating Telephone Engineering Problems

Enough has been said, I believe, in the foregoing to indicate the general nature of the engineering problems handled in the Bell System. It is, of course, impracticable and doubtless would be tiresome in a talk of this character to deal specifically with many detailed engineering problems involved in the work which I have just described in general terms. I believe that you will gather a better appreciation of what some of these problems are from the inspection trips which form an important part of this week's program, than you could by a full discussion of them here. It will probably be of interest, however, before closing to outline briefly one or two typical telephone engineering problems of considerable magnitude.

New York-Chicago Toll Cable

The first large engineering problem I will consider is that relating to the New York-Chicago toll cable as shown in Fig. 1. This cable follows a route from New York through Harrisburg, Pittsburg, Newcastle, Cleveland, and thence to Toledo, and when completed[1] will extend to South Bend and then on to Chicago. For parts of the distance through the congested sections it is underground, and through the open country it is aerial.

Until a comparatively few years ago practically all long toll circuits were in open wire construction; that is, individual wires mounted on separate insulators attached to cross-arms on poles. This was a natural development at first, due to the small number of circuits usually involved, but was also necessary because of the relatively high transmission losses of cable circuits where, as you know, the wires are insulated by wrappings of paper, closely twisted together in pairs and quads, and large numbers of these compressed together within a lead sheath. The rapidly increasing use of toll service, however, pointed to difficulties in providing for future growth with open wire lines. In different parts of the route between Chicago and New York, for example, there were three and four heavily loaded open wire toll lines and the rate of growth was so rapid it was evident that before long difficulty would be experienced in obtaining suitable routes for the additional pole lines required.

Early efforts were accordingly made to devise means which would permit of satisfactory talks through cable and as a result of very intensive research there were developed satisfactory forms of telephone

[1] This cable has recently been completed.

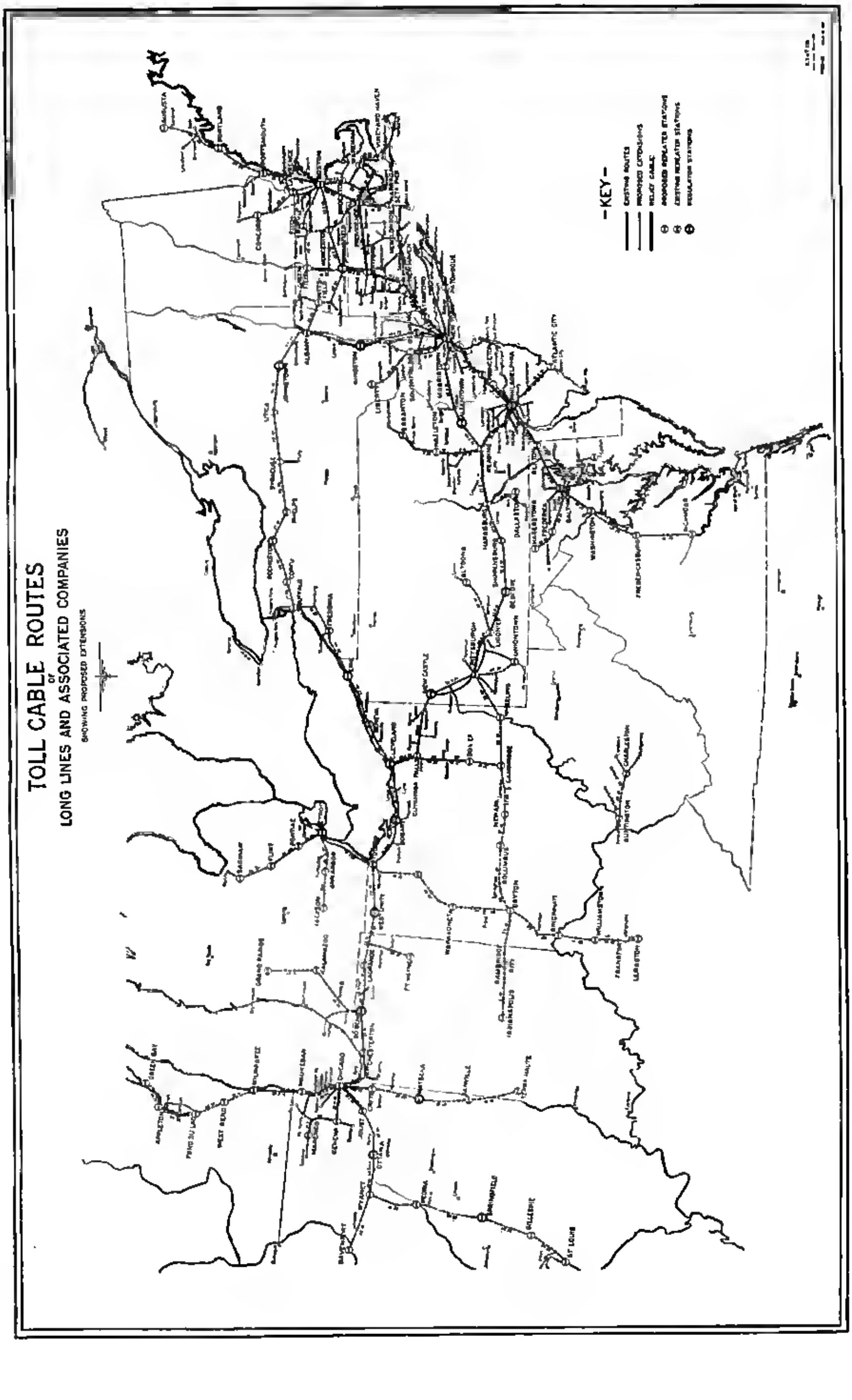
TOLL CABLE ROUTES
OF
LONG LINES AND ASSOCIATED COMPANIES
SHOWING PROPOSED EXTENSIONS
-KEY-

Fig. 1

repeaters; that is, devices for amplifying feeble telephone currents, passing in either direction over a telephone circuit, without appreciable distortion. The most successful repeaters of this type, as you may know, use as the amplifying element the vacuum tube, although the tube itself is but a very small part of the apparatus required for the successful operation of the telephone repeater, and many interesting

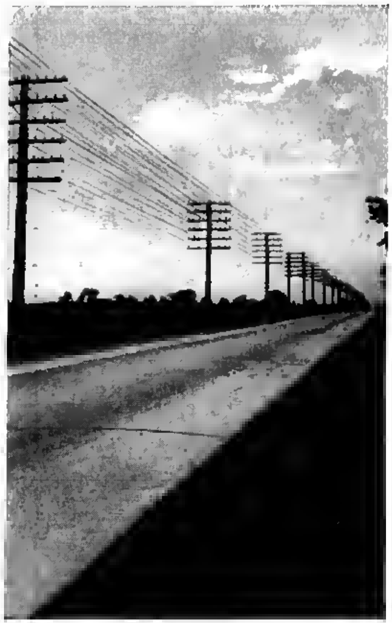

Fig. 2—Open wire toll line

engineering problems had to be solved in providing a complete repeater. A full discussion of this very important and interesting development is given in a paper by Mr. Gherardi and Dr. Jewett, published in the Transactions of the A. I. E. E. for 1919.

The toll cable development, based on the use of repeaters as outlined above and many other technical improvements, now makes it possible to give satisfactory service between Chicago and New York and intermediate points over toll cable circuits of such small gauge that close to 300 circuits can be included in a single sheath of 2⅝″ in diameter. The same number of circuits would require four or five very heavily built pole lines of open wire construction such as is shown in Fig. 2.

The construction of the Chicago-New York cable was started in 1918 and will be completed this year. As shown in Fig. 1, the cable

is now in service between Chicago and South Bend, Indiana, and between New York and points as far west as Toledo. This cable is one element of a very extensive network of toll cables, particularly in

Fig. 3—Transporting cable reels through Allegheny Mountains

Fig. 4—Toll cable line in Allegheny Mountains

the northeastern part of the country. Important cables in service or being installed out of Chicago, in addition to the New York-Chicago cable, include cables from Chicago to St. Louis, Chicago to Terre Haute, Chicago to Milwaukee, Chicago to Davenport, Iowa. During this year the Bell System is installing over 1,000 miles of toll cable containing more than 2 billion 500 million feet of insulated conductor.

The successful operation of long circuits of this cable network has been brought about only by the solution of very difficult technical problems, some of which have already been mentioned. It may be of interest to state that the long through circuits in this cable will be in the nature of four-wire circuits; in other words, one pair of small gauge wires with repeaters will be used for talking in one direction and

Fig. 5—Typical telephone repeater station

a similar pair so equipped will be used for talking in the other direction. As an illustration of another type of problem involved, it may be of interest to mention that it is necessary to employ automatic regulators which vary with changes in the temperature of the cable conductors, the amplification introduced into the circuit by some of the repeaters. Without regulation, the change in temperature occurring within 24 hours often makes as much as a thousand-fold difference in the amount of electrical energy received over New York-Chicago circuit from the same input, a variation which would, of course, utterly prevent giving service over the circuits.

Aside from the electrical difficulties there were also interesting problems of a mechanical engineering nature to overcome in the desing and placing of the cable, particularly where it passes through the wilderness of the Allegheny Mountains as shown in Figs. 3 and 4.

The cable is for most of its distance strung on pole lines and these lines were designed especially to withstand the stresses caused during sleet storms. The decision as to whether the cable should be underground

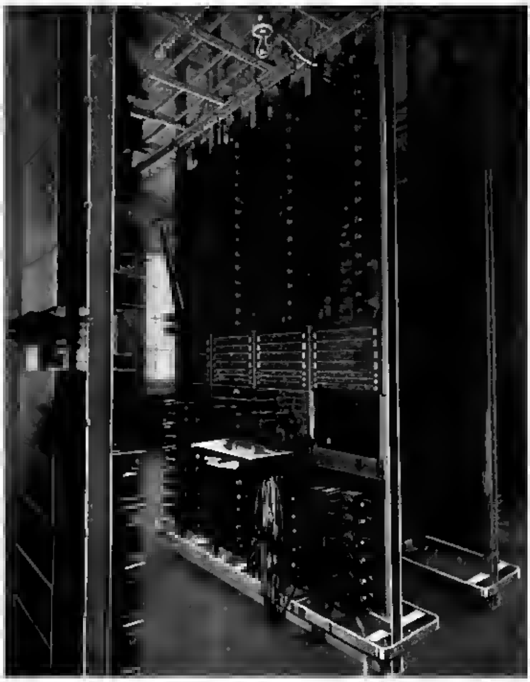

Fig. 6—Bank of 2-wire telephone repeaters

or aerial in the various sections in itself involved many engineering considerations.

In addition to the engineering matters in connection with the cable itself, other interesting problems present themselves, of course, with regard to the design and construction of the telephone repeater stations and their associated equipment, the telephone repeaters being inserted in circuits of this character at intervals of about 50 miles. A typical repeater station is shown in Fig. 5, a bank of two-wire repeaters in Fig. 6, and a bank of four-wire repeaters in Fig. 7.

Fig. 8 shows a view of the completed cable. In this case a loading coil case is also shown, and the picture indicates again the physical problem of erecting a cable through the less accessible sections of the territory. Fig. 9 shows another section of the completed cable through open country, and shows loading coil construction and facilities for

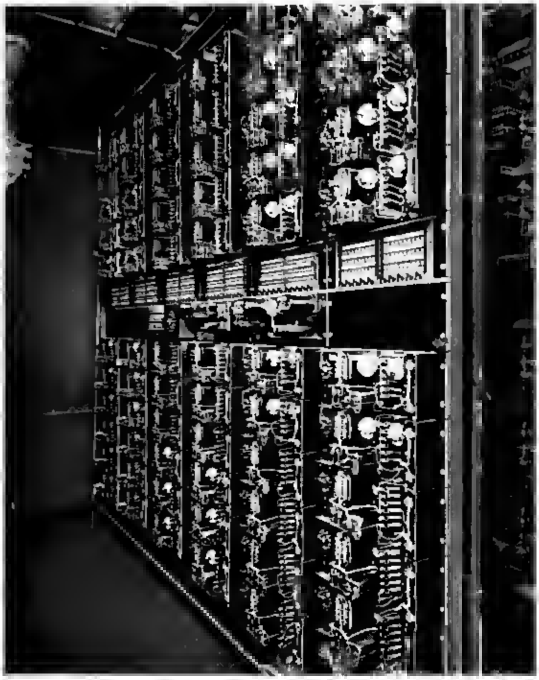

Fig. 7—Bank of 4-wire telephone repeaters

Fig. 8—Toll cable line showing loading coil case

cutting in additional loading coils as required. Fig. 10 gives an interesting view of the cable over the Alleghenies, showing us again the mechanical problems involved in design and construction. In this case the cable follows closely the open wire line, which in time will be dismantled.

It may be of interest in this connection to state that the plans to be compared in the study of toll cable projects generally differ primarily in the dates at which they contemplate supplementing or replacing open wire service by cable. Conditions under which cable becomes economical depends, of course, on many factors. Perhaps the most important single factor is the rate of growth of the circuit requirements. The detailed design of the cable also involves very interesting studies of the economical number of circuits to provide in the cable sheath. Also the economical gauge of each circuit must be considered, comparing in many cases the economies of a larger gauge with those of a smaller gauge provided with a greater number of telephone repeaters.

The design of the toll cable as discussed is but one illustration of the design of the toll plant extension as a whole, a problem which, in general, involves the consideration of the relative desirability of additions to existing open wire toll lines, building new open wire toll lines, applying carrier telephone systems to existing lines or installing toll cable.

Telephone Problem in New York City

As another specific illustration of the telephone engineering problem, I will describe briefly the matter of adequately meeting requirements in a large city, using for purposes of illustration the situation in New York City and the metropolitan area. This particular situation doubtless presents one of the most difficult engineering problems and in some respects is unusual, yet, on the other hand, it fairly represents the kind of engineering problem with which the Bell System engineers must deal at all times.

Fig. 11 indicates clearly the magnitude of the present and future problem in the New York metropolitan area, as viewed from the number of telephones. In 1905 there were 220,000 stations in New York City and 300,000 stations in the metropolitan area. By 1925 the figures had increased to 1,400,000 for New York City and 1,900,000 for the entire area. By 1945 it is estimated there will be over 3,000,000 stations in New York City and over 4,000,000 in the metropolitan area. Part of this growth can be ascribed to the normal increase in the population and part, of course, to the tendency to make more use of

Fig. 9—Toll cable line through open country

Fig. 10—Cable and open wire toll line in Allegheny Mountains

the telephone. In addition, part of the growth is due to the conditions following the World War and the general economic trend.

Comparing 1924 with 1914, wholesale commodity prices, as you know, have risen over 50 per cent; the cost of living over 60 per cent; wages in manufacturing industries over 100 per cent, while in the same period telephone rates generally have increased less than 30 per cent.

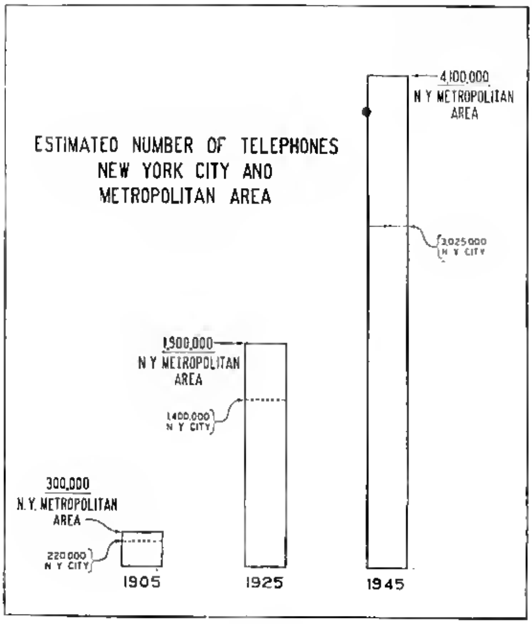

Fig. 11

and even less than this in some of the larger cities. Telephone service, therefore, represents a large value for its price and in a situation like Greater New York City, where there are between seven and eight million people, it is but natural that the new situation in the economic balance of things, together with the low price of service shown, would make for a very substantial increase in the demand for telephone service. This has, of course, also been true elsewhere.

As I have shown there are at present a total of over one million telephone stations within New York City proper served from about 130 central offices, 26 offices having been added last year. The predictions are that within the next twenty years the stations and central offices will have more than doubled. Each subscriber in this great network must be able to reach promptly every other subscriber.

Due to the large area involved, a great number of calls within the city necessitates extra charges, which means that they must be specially supervised and recorded. There are many different classes of service furnished the public, such as measured rate, flat rate, coinbox, etc., and, of course, such other special services as Information service. Not only individual lines but party lines and private exchanges must be cared for. Furthermore, the demands for service to the extensive area surrounding this great city, as well as the large number of cities, towns and rural communities throughout the entire country, require that provision be made for thousands of toll messages daily. The problem of giving satisfactory service under these conditions and under the complications that come with the tremendous growth referred to is a very important one and requires careful and constant study.

In order to properly care for this complex problem of furnishing telephone service in large cities, telephone engineers in line with the efforts which have been made from the time of the early switchboards have endeavored to perform the various operations automatically so far as consistent with service requirements. While the switchboards which you saw yesterday are called "manual" switchboards, you doubtless noted from the demonstration and your visit through the central office that many of the operating features are automatic in character. The latest step in this general trend of development has been to develop a switchboard which would provide for completing many classes of calls entirely without the aid of an operator, and these new machine switching equipments which you will see today are gradually being introduced into New York, Chicago, and other large cities. This is a large problem in itself and involves not only the completion of calls from machine switching subscribers to other machine switching subscribers, but the completion of calls incoming to machine switching offices from manual offices and outgoing to manual offices. This must be done without reaction on the service or inconvenience to the subscribers and so that the machine equipment and the manually operated switchboards will work together as a coordinated whole.

I do not know of any mechanical device that reminds one so much of the functioning of the human brain as does this mechanism for completing calls following the dialing operation. The completion of a simple call, while quite involved in itself, is by no means the complete problem. There must be a great many other features provided, such, for one example, as where a register is provided on the subscriber's line to register the number of calls under measured rate service. In these cases it is necessary to insure that there shall be

proper registration by the machine and the mechanism is so arranged, therefore, that on the completion of the call it will test the line to make sure that everything was normal before registration is actually performed. Similarly, all the way through the completion of the regular and special classes of calls it is necessary for the mechanism to perform just such intricate functions as that described.

The engineering of the interoffice trunk layout in a city like New York is also an important and interesting problem, not only because of its magnitude but because of the almost unlimited variations which

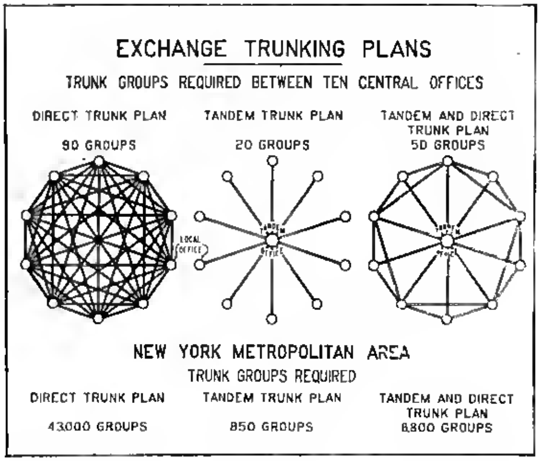

Fig. 12

might be employed, a large number of which must be carefully considered in connection with additions to the plant. In opening new central offices, trunk circuits must be provided between each new office and the existing offices and also between the new offices themselves.

Fig. 12 illustrates the range of trunking layouts which might be used. With the 10 offices assumed and direct trunks between each office and every other office, 90 groups of trunks would be required. With the so-called full tandem operation; that is, under an arrangement whereby each office reaches every other office through a central point, 20 groups of trunks would be required. Between these two extremes with some offices reaching certain other offices through the tandem center and certain others by direct trunks, a great many combinations would be possible. In the case assumed 50 groups appeared to be the best combination. The data given at the bottom of Fig. 12 are of particular interest in this connection. As will be

noted, if only direct trunks were employed in the metropolitan area, some 43,000 groups would be required. On the other hand, if we followed only the strictly tandem plan, 850 groups would be required but as previously indicated, unwarranted switching costs would be

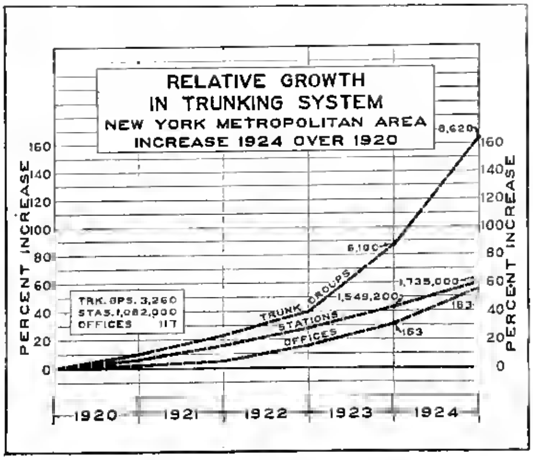

Fig. 13

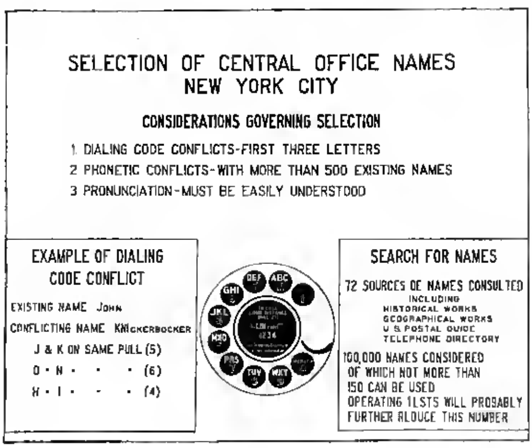

Fig. 14

involved. By establishing a plan, however, involving both tandem and direct trunks, the most economical plan can be determined upon and in this case about 9,000 groups of trunks are required. Fig. 13 shows how rapidly the trunk groups increase with the addition of stations and central offices. You can well imagine the engineering

problem involved in working out the most efficient trunking plan for a city such as New York or Chicago.

Aside from the layout of the trunk plant itself, the engineering work involves the design and construction of the underground subway system and the design of the physical cable plant. In one year in

Fig. 15—Bowling Green telephone building, New York City

New York City alone, enough cable has been installed and placed in service to make a cable containing 1,200 wires reaching from New York to Chicago.

The expansion of the metropolitan plant to care for the increase in the number of subscribers also involves, of course, opening many new offices and the provision of new switchboards and additions to the existing switchboards. The matter of selecting the name for a new central office would at first appear to be a simple one, but as indicated by Fig. 14 it is a very involved problem in itself. As will be noted, there are many questions to be considered. One feature relates to the matter of dialing. It is interesting to note from Fig. 14, however, that while the name "John" does not seem in any way to conflict with the name "Knickerbocker," yet these two names could not be

used together in the same city because of conflict in the dialing process. Phonetic conflicts are also exceedingly important in telephone operation. In fact, they form one of the most important factors that must be considered in the selection of an office name. Pronunciation of the name must also be easily understood. Thus we find that in the case of the metropolitan area something like 72 sources of names were consulted; for instance, historical works, geographical works, postal

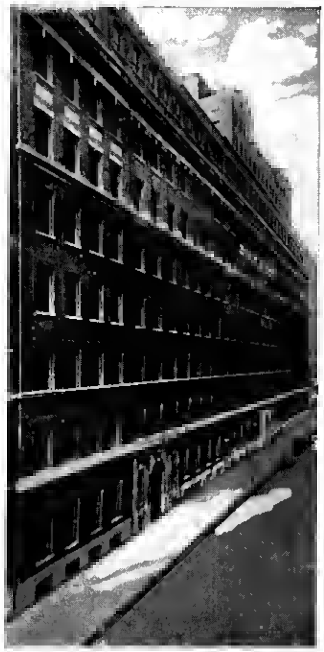

Fig. 16—West 36th Street building, New York City

guides, telephone directories, and other sources, and out of 100,000 names considered not more than 150 could be used and possibly some of these on further study will have to be eliminated. I have mentioned this detail of operation simply to illustrate the variety of the problems for the telephone engineer and the extent to which he must consider them in order to insure the grade of service we are all striving for.

The erection of new buildings and additions to existing buildings is also a large problem, there being 12 new buildings and 21 additions erected in New York during 1923 and 1924. It might be interesting to note that for these buildings and equipments it is necessary to consider not only the proper association of the various elements of the

central office unit from the viewpoint of securing satisfactory operation and maintenance conditions, but also to provide for an orderly growth of the different parts of equipment and building. Further, the central office layout must be considered from the point of view of costs which

Fig. 17—Long distance telephone building, New York City

may vary over a wide range under the different arrangements which might be used. This you will better appreciate from your visits through the offices.

I will next show you a few cases which will illustrate some of the problems in the way of providing building space to house switchboard equipments in these large metropolitan areas.

Fig. 15 is a photograph of the Bowling Green building, located in the extreme lower end of Manhattan Island and which will provide space for switchboard requirements for that part of New York City.

Fig. 16 gives a rather interesting example of another of the large New York telephone buildings, this case being the one located in West 36th Street in the neighborhood of the Pennsylvania Station. This

building and equipment involve an expenditure of $15,000,000 and is equipped to serve over 100,000 stations. In other words, we find in this one building and the associated switchboards on subscriber's premises, provision for handling more stations, for example, than are in service in a city the size of Baltimore, with a population of nearly

Fig. 18—Barclay-Vesey telephone building under construction, New York City

800,000, giving you a further idea of the problem of providing service in these large metropolitan centers.

Fig. 17 illustrates the building in New York devoted to the centering of all long distance lines. Facilities are also provided for connecting together the various offices of the city for switching to suburban points through one of those tandem boards of which I spoke, as well as for switching to the great network of toll lines running out to all important points throughout the country. While there are some local switchboard facilities in this building, practically all the space is devoted to handling toll traffic.

Fig. 18 illustrates the new building being built for the New York Telephone Company on West Street in the lower part of Manhattan. This building is designed to house a large number of units of machine switching equipment, and the upper part will be utilized for the administrative offices of the Company. This further illustrates the type of building required in these large centers, and the many engineering problems involved.

I might go on at length, giving one problem after another, by way of illustration, but I think enough has been said to give you a general idea of the nature and great variety of the telephone engineering problem involving, as it does, almost every phase of the mechanical, electrical, and other arts. It is obviously necessary for the engineer not only to consider the technical problems involved in each of these matters, but to a greater extent it seems to me than almost any other situation I have encountered, it is necessary for him to take into account all of the related broad operating and business factors which are naturally to be found in an industry of the magnitude of the Bell System.